Department I - C Plus Plus

Modern and Lucid C++ for Professional Programmers

Week 13 – Initialization and Aggregates

Thomas Corbat / Felix Morgner
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Goals

- **You can recognize and name different kinds of initialization**
- **You can explain the contraints imposed on aggregate types**
- **You can implement aggregate classes**

Topics

- **Recap Week 12**
- **Errata/Andeda Week 12**
- **Different Kinds of Initialization**
- **Aggregate Types**

Recap Week 12

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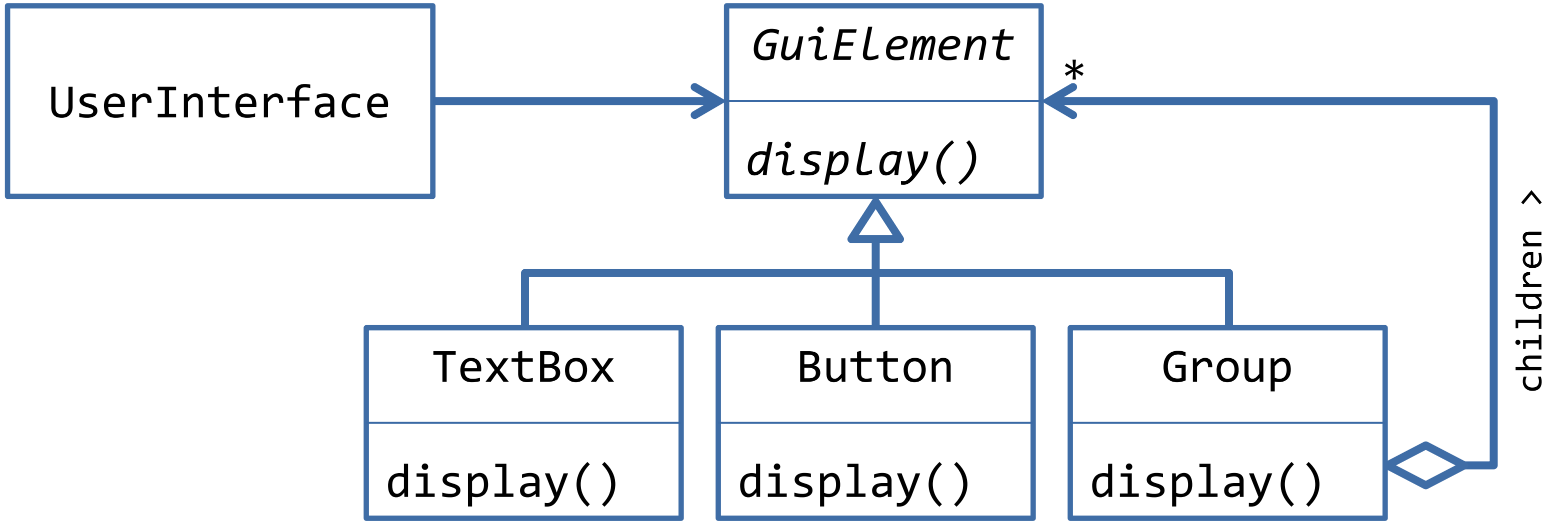
- **Mix-in of functionality from empty base class**
  - Often with own class as template argument (CRTP) e.g., `boost::equality_comparable<T>`
  - No inherited data members, only added functionality

```
struct Date : boost::equality_comparable<Date> {
  //...
};
```

- **Adapting concrete classes**
  - No additional own data members
  - Convenient for inheriting member functions and constructors

```
template<typename T, typename Compare>
struct indexableSet : std::set<T, Compare> {
  //...
};
```

- **Implementing a design pattern with dynamic dispatch**
  - e.g., Strategy, Template Method, Composite, Decorator
  - Provide common interface for a variety of dynamically changing or different implementations
  - Exchange functionality at run-time
- **Base class/interface class provides a common abstraction that is used by clients**



- **To override a virtual function in the base class the signature must be the same**
- **Constness of the member function belongs to the signature**

```
struct Base {
  virtual void sayHello() const {
    std::cout << "Hi, I'm Base\n";
  }
};

struct Derived : Base {
  void sayHello() override {
    std::cout << "Hi, I'm Derived\n";
  }
};

struct OtherDerived : Base {
  void sayHello(std::string name) const override {
    std::cout << "Hi " << name << ", I'm OtherDerived\n";
  }
};
```

Abstract Base Classes: Pure Virtual

- **There are no interfaces in C++**
- **A pure virtual member function makes a class abstract**
- **To mark a virtual member function as pure virtual it has zero assigned after its signature**
  - = 0
  - No implementation needs to be provided for that function

```
struct AbstractBase {
  virtual void doitnow() = 0;
};
```

- **Abstract classes cannot be instantiated (like in Java)**

```
AbstractBase create() {
  return AbstractBase{};
}
```

- **You can declare the copy-operations as deleted**

```
struct Book {
  //...
  Book & operator=(Book const & other) = delete;
  Book(Book const & other) = delete;
};

struct EBook : Book {
  //...
 EBook(EBook const & other) :
    Book{pages},
    currentPageNumber{other.currentPageNumber}{}
  EBook & operator=(EBook const & other) {
    pages = other.pages;
    currentPageNumber = other.currentPageNumber;
    return *this;
  }
};
```

```
void readBook(Book book);

int main() {
  EBook designPatterns{"..."};
  readBook(designPatterns);

  EBook refactoring{"..."};
  Book & some = designPatterns;
  some = refactoring;
  EBook copy = designPatterns;
  copy = refactoring;
}
```

Errata/Andenda Week 12

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```cpp
struct Base1 {
  explicit Base1(int value) {
    std::cout << "Base1 with argument " << value << "\n";
  }
};

struct Base2 {
  Base2() { std::cout << "Base2\n"; }
};

class DerivedWithCtor : public Base1, public Base2 {
  int mvar;
public:
  DerivedWithCtor(int i, int j)
      : mvar{j}, Base2{}, Base1{mvar} {}
};

int main() {
  DerivedWithCtor dwc{1, 2};
}
```

Mixed Example

```cpp
struct Animal {
  void makeSound() {cout << "---\n";}
  virtual void move() {cout << "---\n";}
  Animal() {cout << "animal born\n";}
  ~Animal() {cout << "animal died\n";}
};

struct Bird : Animal {
  virtual void makeSound() {cout << "chirp\n";}
  void move() {cout << "fly\n";}
  Bird() {cout << "bird hatched\n";}
  ~Bird() {cout << "bird crashed\n";}
};

struct Hummingbird : Bird {
  void makeSound() {cout << "peep\n";}
  virtual void move() {cout << "hum\n";}
  Hummingbird() {cout << "hummingbird hatched\n";}
  ~Hummingbird() {cout << "hummingbird died\n";}
};
```

```cpp
int main() {
  cout << "(a)----------------------------\n";
    Hummingbird hummingbird;
    Bird bird = hummingbird;
    Animal & animal = hummingbird;
  cout << "(b)-----------------------------\n";
    hummingbird.makeSound();
    bird.makeSound();
    animal.makeSound();
  cout << "(c)-----------------------------\n";
    hummingbird.move();
    bird.move();
    animal.move();
  cout << "(d)-----------------------------\n";
}
```

- **What is the output?**
- **What is the bad with this code's design?**

Kinds of Initialization

- **Default Initialization**
- **Value Initialization**
- **Direct Initialization**
- **Copy Initialization**
- **List Initialization**
- **Aggregate Initialization**

- **The kind depends on the context**
  - Four general syntaxes

1. **Nothing**
2. `( expression list )`
3. `= expression`
4. `{ initializer list }`

- **Simplest for of initialization**
  - Simply don’t provide an initializer
  - Effect depends on the kind of entity we declare
  - Does not work for references!
- **Danger lurks when using default initialized entities**
- **Does not necessarily work with `const`**
  - The object must have a “valid” value

```
int global_variable; // implicitly static

void di_function() {
  static long local_static;

  long local_variable;
}

struct di_class {
  di_class() = default;

  char member_variable; // not in ctor init list
};
```

- **Static variables are**
  - zero initialized first,
  - then their type’s default constructor is called

```
int global_variable; // implicitly static

std::string global_text;

void di_function() {
  static long local_static;
}
```

- **If the type cannot be default constructed, the program is ill-formed!**

```
struct blob {
  blob(int);
};

blob static_instance;
```

Suppresses Default Constructor

```
error: no matching function for call to 'blob::blob()'
```

Default Initialization (Effects)

- **Non static integral and floating point variables are uninitialized**
- **Objects of class types are constructed using their default constructor**
- **Member variables not in a ctor-init-list are default initialized**
- **Arrays initialize all of their elements accordingly**

```
void di_function() {
  long local_variable;
  std::string local_text;
}

struct di_class {
  di_class() = default;
  char member_variable; // not in ctor init list
};
```

Default Initialization

- **Danger lurks!**
  - Reading an uninitialized value incurs undefined behavior!

```
void print_uninitialized() {
  int my_number;
  std::cout << my_number << '\n';
}
```

- **Initialization performed with empty ( ) or { }**
  - { } is preferrable, since it works in more cases
- **Invoked the default constructor for class types**

```
#include <string>
#include <vector>

void vi_function() {
  int number { };
  std::vector<int> data { };
  std::string actually_a_function();
}
```

- **Similar to Value Initialization**
  - Uses non-empty ( ) or { }
  - When using { } only applies if not a class type (see List Initialization)
- **“Most vexing parse” lurks with ( )**
  - Prefer { … }

```
#include <string>

void diri_function() {
  int number{32};
  std::string text("CPl");
  word vexing (std::string());
}
```

- **Two interpretations**
  - Initializition with a value-initialized string
  - Declaration of a function returning word and taking an unnamed pointer to a function returning a string
- **The first is what we would expect**
- **The second is the one the standard requires!**
  - Therefore, prefer { … }

```
word vexing (std::string());
```

- **Initialization using =**
  - If the object has class type and the right hand side has the same type
    - If the right hand side is a temporary, the object is constructed “in-place”
    - Otherwise, the copy constructor is invoked
  - Otherwise, a suitable conversion sequence is searched for
- **Also applies to return statements and throw/catch**

```cpp
#include <string>

std::string string_factory() { return ""; }

void ci_function() {
  std::string in_place = string_factory();
  std::string copy = in_place;
  std::string converted = "CPl";
}
```

- **Uses non-empty { }**
  - Direct List Initialization

```
std::string direct { "CPl" };
```

  - Copy List Initialization

```
std::string copy = { "CPlA" };
```

- **Constructors are selected in two phases**
  - If there is a suitable constructor taking `std::initializer_list`, it is selected
  - Otherwise, a suitable constructor is searched

List Initialization (Pitfall)

- **Since the std::initializer_list constructor is preferred, you might run into trouble**

```cpp
// vector(size_type count,
//        const T& value,
//        const Allocator& alloc = Allocator());

int ouch() {
  std::vector<int> data{10, 42};
  return data[5];
}
```

Aggregate Types

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- **Simple class types**
  - Can have other types as public base classes
  - Can have member variables and functions
  - Must not have user-provided, inherited or explicit constructors
  - Must not have protected or private direct members
- **Mostly used for “simple” types**
  - No invariant that has to be established
  - Example: DTOs
- **Arrays are also Aggregates**

```
struct person {
  std::string name;
  int age{42};

  bool operator<(person const & other) const {
    return age < other.age;
  }

  void write(std::ostream & out) const {
    out << name << ": " << age << '\n';
  }
};


int main() {
  person rudolf{"Rudolf", 32};
  rudolf.write(std::cout);
}
```

Aggregates (Counter-Example)


```
struct db_entry {};

struct person : private db_entry {
  std::string name;
  int age{42};

  bool operator<(person const & other) const {
    return age < other.age;
  }

  void write(std::ostream & out) const {
    out << name << ": " << age << '\n’;
  }
};
```

Aggregate Initialization

- **Special case of List Initialization**
  - If the type is an aggregate, the members and base classes are initialized from the initializers in the list
- **If more elements than members (or bases) are given the program is ill-formed**
- **Can also provide less initializers than there are bases and members:**
  - If the “uninitialized” members have a member initializer, it is used
  - Otherwise they are initialized from empty lists

```
person rudolf{"Rudolf"};
```

Age will be set to 42

Summary

- **Numerous different kinds of initialization**
  - Avoid default initialization because of possible UB
  - Generally, prefer initialization with { }
  - Use ( ) only when aiming for a certain constructor (avoiding std::initializer_list constructors)
- **Aggregates can reduce code for simple types**
  - Only use them if you type has no invariant